Pacing in age-group freestyle swimmers at The XV FINA World Masters Championships in Montreal 2014

Nikolaidis, Pantelis T ; Knechtle, Beat

Abstract: Pacing strategies have been investigated for elite-standard freestyle swimmers, but little is known about pacing in age-group freestyle swimmers. We investigated changes in swimming time across distances in 4,481 women and men swimmers who competed in 100, 200, 400, and 800 m freestyle age groups from 25-29 years to 90-94 years in the FINA World Masters Championships 2014. In 100 to 800 m, there was a small lap×sex interaction ($P < 0.001$, $0.033 \leq \eta(2) \leq 0.045$) whereby women had larger lap-to-lap changes in swimming time than men. From 100 to 800 m, there were moderate to large lap×age group interactions ($P < 0.001$, $0.054 \leq \eta(2) \leq 0.235$), i.e., pacing patterns differed by age groups. There were small main effects of lap on time in 100, 200, 400 and 800 m freestyle events ($P < 0.001$, $0.033 \leq \eta(2) \leq 0.045$). In summary, (i) the largest increase in swimming time occurred during the second lap and a decrease in time occurred during the last lap, except in the 100 m, and (ii) the effect of participants' sex on lap time indicated larger percentage changes of pacing in women than in men. These findings should help coaches to develop age- and event-tailored pacing strategies.

DOI: https://doi.org/10.1080/02640414.2016.1213412

Originally published at:
Nikolaidis, Pantelis T; Knechtle, Beat (2017). Pacing in age-group freestyle swimmers at The XV FINA World Masters Championships in Montreal 2014. Journal of Sports Sciences, 35(12):1165-1172.
DOI: https://doi.org/10.1080/02640414.2016.1213412

Pacing in age-group freestyle swimmers at The XV FINA World Masters Championships in Montreal 2014

Running head: Pacing in master swimmers

Pantelis T. Nikolaidis [1], Beat Knechtle [2,3]

[1] Department of Physical and Cultural Education, Hellenic Army Academy, Athens, Greece

[2] Gesundheitszentrum St. Gallen, St. Gallen, Switzerland

[3] Institute of Primary Care, University of Zurich, Zurich, Switzerland

Corresponding author
Prof. Dr. med. Beat Knechtle
Facharzt FMH für Allgemeinmedizin
Gesundheitszentrum St. Gallen
Vadianstrasse 26
9001 St. Gallen
Switzerland
Telefon +41 (0) 71 226 93 00
Telefax +41 (0) 71 226 93 01
e-Mail beat.knechtle@hispeed.ch

Abstract

Pacing strategies have been investigated for elite-standard freestyle swimmers, but little is known about pacing in age-group freestyle swimmers. We investigated changes in swimming time across distances in 4,481 women and men swimmers who competed in 100 m, 200 m, 400 m, and 800 m freestyle age groups from 25-29 years to 90-94 years in the FINA World Masters Championships 2014. In 100 m to 800 m, there was a small lap×sex interaction ($P < 0.001$, $0.033 \leq \eta^2 \leq 0.045$) whereby women had larger lap-to-lap changes in swimming time than men. From 100 m to 800 m, there were moderate to large lap×age group interactions ($P < 0.001$, $0.054 \leq \eta^2 \leq 0.235$) i.e. pacing patterns differed by age groups. There were small main effects of lap on time in 100 m, 200 m, 400 m and 800 m freestyle events ($P < 0.001$, $0.033 \leq \eta^2 \leq 0.045$). In summary, (*i*) the largest increase in swimming time occurred during the second lap and a decrease in time occurred during the last lap, except in the 100 m, and (*ii*) the effect of participants' sex on lap time indicated larger percentage changes of pacing in women than in men. These findings should help coaches to develop age- and event-tailored pacing strategies.

Key words: athlete, master, age group, performance

Introduction

There has been an increasing scientific interest about master athletes, because they have been considered as a model of successful ageing (Tanaka & Seals, 2008). Swimming is one of the most popular sports with many older people practising it at a recreational level and a large number of master athletes (whose number has increased during the last decades) participating in official sport events such as the FINA (Fédération Internationale de Natation) World Masters Championship (Rubin & Rahe, 2010). Most of the studies on master swimmers have focused on physiological and biomechanical determinants of performance and how these determinants varied by age (Reaburn & Dascombe, 2008; Tanaka & Seals, 2008), whereas pacing strategies, which are also a factor of performance, have been less studied.

Pacing in sports describes the strategy of an athlete by which effort is managed across an exercise bout for a specific goal and in the knowledge of the likely demands of the task (Edwards & Polman, 2012). Abbiss and Laursen (2008) described six pacing strategies in athletic performance such as negative pacing (*i.e.* increase in speed over time), positive pacing (*i.e.* continuous slowing over time), all-out pacing (*i.e.* maximal speed possible), even pacing (*i.e.* same speed over time), parabolic-shaped pacing (*i.e.* positive and negative pacing in different segments of the race) and variable pacing (*i.e.* pacing with multiple fluctuations).

In swimming, pacing in elite-standard athletes has been investigated (Lipińska, Allen, & Hopkins, 2015; 2016; Skorski, Faude, Caviezel, & Meyer, 2014). Freestyle swimmers tend to adopt a parabolic-shaped pacing. For example, in elite-standard women 800 m freestyle swimmers, the speed profile was a shallow negative quadratic with longest time in the eleventh lap. The first and the last laps (lengths) took less time than the other laps (Lipińska et al., 2015). In elite-standard 400 m freestyle swimmers, fast-start-even and parabolic pacing profiles were the most frequently used (Mauger et al., 2012).

However, in addition to elite-standard athletes, since 1986, age-group swimmers have competed in FINA World Masters Championships (www.fina.org/discipline/masters). While we have some knowledge about the pacing in freestyle swimming for elite-standard swimmers (Lipińska et al., 2015; Mauger et al., 2012; Robertson et al., 2009), we have no data about pacing in age-group freestyle swimmers. The present study investigated changes in swimming time by laps in age group swimmers (*i.e.* age groups from 25-29 years to 90-94 years) competing in the FINA World Masters Championships 2014 in 100 m, 200 m, 400 m, and 800 m freestyle.

Materials and Methods

Ethics approval

The study was approved by the Institutional Review Board of St. Gallen, Switzerland.

Data sampling and data analysis

All data were obtained from the official and publicly accessible website of the FINA at www.fina.org/content/fina-masters-world-championships-results-archive. In the XV FINA World Masters Championships held in Montreal (Canada) in 2014, for each distance from 100 m to 800 m and each swimmer, times for each 50 m length (except 100 m lap in 800 m event) were recorded. A total of 4,481 women and men swimmers who competed in 100 m, 200 m, 400 m, and 800 m freestyle were considered (Table 1). We included all women and all men for every 5-year age groups from 25-29 years to 90-94 years to avoid a selection bias by analyzing only a limited sample of top athletes such as the top 10 or top 100 of each age group.

Statistical analyses

Statistical analyses were performed using IBM SPSS v.20.0 (SPSS, Chicago, USA). Data were expressed as mean and standard deviation (*s*). A mixed-design factorial ANOVA compared effects of lap and participants' sex on swimming time, where the within-groups factor was lap and the between-groups factor was participants' sex. Moreover, a mixed-design factorial ANOVA compared effects of lap and age group on swimming time separately for each sex, where the within-groups factor was lap and the between-groups factor was age group. Subsequent comparisons among laps were carried out using post-hoc Bonferroni test. The magnitude of differences among laps was examined using effect size eta squared (η^2) and evaluated as: small ($0.010<\eta^2\leq0.059$), moderate ($0.059<\eta^2\leq0.138$) and large ($\eta^2>0.138$) (Cohen, 1988). In addition, comparison of a lap time was via the preceding lap time and was expressed as a percentage using the formula 100×(lap time–preceding lap time)/preceding lap time. We also compared variations in pace by participants' sex and age by a mixed-effects regression model. In this model, swimmers were assigned as random variable, whereas sex, age group and lap were assigned as fixed variables. We examined interaction effects among these fixed variables. Akaike information criterion (AIC) was used to select the final model. These analyses were performed for each swimming event (*i.e.* 100 m, 200 m, 400 m and 800 m) separately. Statistical significance was set at alpha=0.05.

Results

Table 2 summarizes the swim times for women and men for the different age groups. In the 100 m, there was a small lap×sex interaction ($P < 0.001$, $\eta^2 = 0.045$), *i.e.* pacing patterns differed by sex, in which women had a larger increase in swimming time from the first lap (0-50 m) to the second (51-100 m) than men (+11.9 versus +11.3%) (Figure 1). There was a large main effect for lap time ($P < 0.001$, $\eta^2 = 0.801$), in which the second lap took longer than the first (+11.6%). In addition, there was a large lap×age group interaction both in women ($P < 0.001$, $\eta^2 = 0.235$) and in men ($P < 0.001$, $\eta^2 = 0.185$), *i.e.* pacing patterns differed by age group (Figure 2). In women, the age group 85-89 (+15.4%) increased the swimming time in lap 2 the most and the group 35-39 the least (+9.9%). In men, group 80-84 increased race time in lap 2 the most (+16.2%) and the group 75-79 the least (+10.2%).

There was a small lap×sex interaction ($P < 0.001$, $\eta^2 = 0.042$) in 200 m, too (Figure 1). Women and men differed with regards to their pacing patterns (larger changes from lap to lap in women). There was a large main effect of lap ($P < 0.001$, $\eta^2 = 0.847$), in which the second lap was slower than the first one (+11.6%), the third slower than the second (+3.8%) and the last was faster than the third one (–2.1%) (Figure 3). There was a large lap×age group interaction, where pacing patterns differed by age group, in women ($P < 0.001$, $\eta^2 = 0.195$) and in men ($P < 0.001$, $\eta^2 = 0.200$) (Figure 2). In women, swimming time increased the most in lap 2 for the age group 75-79 (+7.3%) and least for the group 30-34 (+3.7%). Time in lap 3, time increased the most for the age group 75-79 (+2.2%) and least for the group 30-34 (+1.3%). In the lap 4, time decreased the most for the age group 80-84 (–2.9%) and least for the group 30-34 (–0.1%). In men, swimming time in lap 2 increased the most for the age group 80-84 (+6.9%) and least for the group 35-39 (+3.0%). In lap 3, time increased the most for age group 70-74 (+2.0%) and least for group 35-39 (+1.0%). In lap 4, time decreased the most for age group 80-84 (–4.2%) and least for group 25-29 (–0.1%). Thus, larger changes in older age groups than in the younger groups occurred in all laps, both in women and men. Also, there was proportionality between the increase in swimming time in lap 2 and its decrease in lap 4: in women, age group 30-34 had least increase in lap 2 and least decrease in lap 4, whereas in men, age group 80-84 had most increase in lap 2 and most decrease in lap 4.

In 400 m (Figure 1), there was a small lap×sex interaction ($P < 0.001$, $\eta^2 = 0.033$), *i.e.* pacing patterns differed by sex, in which women decreased their swimming time from the 150-200 m to the 201-250 m lap (–0.2%) while men increased (+0.2%). There was a large main effect of lap ($P < 0.001$, $\eta^2 = 0.856$), in which swimming time increased during the 50-100 m (+11.1%), 101-150 m (+2.9%), 151-200 m (+1.2%), remained unchanged during the 201-250 m and again increased during the 251-300 m (+0.5%), and finally decreased during the 301-350 m (–0.6%) and 351-400 m (–4.5%) (Figure 3). Moreover, there was a large lap×age group interaction in women ($P < 0.001$, $\eta^2 = 0.176$) and a corresponding moderate interaction in men ($P < 0.001$, $\eta^2 = 0.131$), *i.e.* pacing patterns differed by age group (Figure 2). In women, in lap 2 swimming time increased the most (+15.0%) in group 75-79 and least (+10.3%) in group 30-34, whereas in the last lap it decreased the most in group 75-79 (–6.7%) and least in group 25-29 (–3.0%). In men, time in lap 2 increased the most in group 80-84 (+14.3%) and least in group 50-54 (+9.4%), whereas time in the last lap decreased the most in group 65-69 (–6.2%) and least in group 50-54 (–3.1%). Both in women and men, the largest changes in swimming time occurred in older groups and the smallest in younger groups. A similar trend of proportionality between lap 2 and lap 4 as in 200 m, also occurred in 400 m, e.g. women age group 75-79 and men group 50-54.

There was a small lap×sex interaction ($P < 0.001$, $\eta^2 = 0.034$) in 800 m, too (Figure 1). Women and men differed in their pacing patterns (*i.e.* larger changes from 0-100 m to 101-200 m, from 301-400 m to 401-500 m and in the last lap in women). There was a large main effect of lap ($P < 0.001$, $\eta^2 = 0.842$), in which the swimming time increased during 100-200 m (+8.8%), 201-300 m (+1.0%), 301-400 m (+0.5%), 401-500 m (+0.2%), 501-600 m (+0.2%), and decreased during 601-700 m (–0.3%) and 701-800 m (–3.4%) (Figure 3). There was a small lap×age group interaction in women ($P < 0.001$, $\eta^2 = 0.054$) and a corresponding moderate interaction in men ($P < 0.001$, $\eta^2 = 0.105$), where pacing patterns differed by age group (Figure 2). In women, in lap 2 swimming time increased the most for the age group 65-69 (+9.6%) and least for the group 80-84 (+5.6%), whereas in the last lap, swimming time decreased the most for the age group 60-64 (–4.1%) and least for the group 80-84 (–0.9%). In men, in lap 2 the swimming time increased the most for the age group 80-84 (+12.8%) and least for the group 30-34 (6.9%), whereas in the last lap swimming time decreased the most for the group 80-84 (–5.8%) with the 65-69 group showing an increase (+0.2%). The trend of larger changes in the older groups occurred only in men. However, the trend of proportionality in changes between the second and the last lap also occurred, *e.g.* women age group 80-84 and men group 80-84.

The findings of the mixed-effects regression analysis of the effect of participants' sex, lap and their interaction on swimming time by swimming event are summarised in Table 3, whereas the analysis of the effect of lap, age group and their interaction on swimming time is summarised in Table 4 (women) and Table 5 (men).

Discussion

The main finding of the present study was a general pattern of pacing in the events of 100 m, 200 m, 400 m and 800 m freestyle for master swimmers. The largest increase in swimming time occurred during the second lap and the shortest time was for the last lap, except in the 100 m. In addition to this general pattern, there was a variation in pacing by sex and age group. In 100 m, 200 m and 800 m, larger changes from lap to lap occurred in women than in men. Also, a general trend that older age groups had larger changes than younger groups occurred in all distances and in both sexes.

For the longer distances such as the 400 m and 800 m freestyle, swimmers adopted parabolic pacing (Abbiss & Laursen, 2008), where the first and the last lap were the fastest. This strategy is practically identical to elite-standard swimmers competing in 400 m freestyle swimming where a fast-start-even-and-parabolic pacing strategy was used (Mauger et al., 2012). Also, elite-standard women freestyle swimmers adopted a parabolic-shaped pacing in 800 m, where the first and the last laps were faster by 6.4% and 3.6% (Lipińska et al., 2015). Most probably, the parabolic pacing strategy of a fast first lap, an even pacing throughout the next laps and fast last lap is the most appropriate strategy both for elite-standard and age-group swimmers who competing in high-level races. The length of a swimming performance is also important. When women and men 100-m and 200-m breaststroke swimmers were compared, faster 100-m and 200-m breaststroke swimmers had a greater competency in kinematic variables (*e.g.* swimming speed, stroke rate and stroke length, start, turns and finish) except stroke kinematics, which were unique to each individual (Thompson , Haljand , & MacLaren, 2000).

Influence of participants' sex

Another major finding was the effect of participants' sex on pacing indicating larger changes in swimming time by laps in women than in men. Differences in pacing between women and men elite-standard swimmers have also been reported. In individual medley swimmers competing at international level, men applied a positive pacing strategy in the 200 m and 400 m individual medley events, whereas women applied a negative pacing strategy (Saavedra et al., 2012). However, for other sports, differences in pacing between women and men have been reported. For example, in marathon running, men slow down faster than women (Deaner, Carter, Joyner, & Hunter, 2014). The same has been found in a 5-km run. It was assumed that the sex-based difference in pacing partly reflected differences indecision making, such as over-confidence, risk perception, or willingness to tolerate discomfort (Deaner & Lowen, 2016). Also others reported differences in marathon running between women and men. March et al. (2011) reported that older runners, women, and faster runners are better pacers than younger runners, men, and slower runners, respectively. Nevertheless, both in women and men, similar patterns of difference occurred among age groups' pacing.

Influence of age

There was a larger effect of age group on pacing than participants' sex. Particularly, we identified larger changes in swimming time by lap in the older age groups than in the younger groups. The age groups, who exhibited the larger increase in swimming time in the second lap, showed the largest decrease in time in the last lap and *vice versa*. We hypothesized that since the faster age group swimmers were the younger in the present study, we would find smaller changes in the younger than in the older age groups. Thus, the observed lap×age group interaction could be attributed to the slower swimming time of the older groups. This agreed with research on pacing in the marathon that identified stable pacing, *i.e.* smaller changes in the faster runners than in the slower (March et al., 2011). A curvilinear decline in endurance performance in swimming from the age 35 years to approximately the age of 60-70 years has been reported (Reaburn & Dascombe, 2008).

This decline has been attributed to age-related decreases in maximal oxygen uptake, maximal heart rate, stroke volume, arteriovenous oxygen difference, active muscle mass, type II muscle fibre size and blood volume (Reaburn & Dascombe, 2008). Thus, effects of age group on pacing might be because of age-related differences in performance and physiological characteristics. However, age-related physiological characteristics might vary by sport. In contrast to 400 m, which lasted ~5-10 min, and 800 m event (~10-20 min duration), that rely mostly on aerobic energy transfer systems, 100 m (1-2 min duration) is considered a high-intensity event with 200 m (2-5 min duration) requiring a combination of aerobic and anaerobic mechanisms (Reaburn & Dascombe, 2009). Accordingly, the age group effect on pacing in 100 m should be attributed to age-related decreases in morphological characteristics, muscle contractile properties, enzyme activity and lactate production (Reaburn & Dascombe, 2009), whereas age group effects on pacing in 800 m would be mostly attributable age-related decrease in aerobic measures such as maximal oxygen uptake (Reaburn & Dascombe, 2008).

Limitations

The findings of the present study concerned the FINA Masters World Championships' free style swimmers who can be considered to be the best age-group competitors in the world. Thus, the pacing patterns identified should be generalized only to swimmers of similar level, because in lower level swimmers, different pacing (*e.g.* larger changes from lap to lap) is likely. Another limitation of the findings of this study might be technical characteristics of the swimming pool where the particular sport event took place; it was outdoors with 50 m length. Performances in shorter pools (25m) probably impose different physiological demands because of the additional turns (*e.g.* turns and in particular the "push" parts off the wall, aid swimmers). Since the championship took place outdoors under particular environmental conditions (*e.g.* water and air temperature), caution is needed to generalize these findings in races under different environmental conditions. Moreover, the present study focused on data analysis of laps and did not consider other aspects, such as start times, turn times and stroke characteristics (Veiga, Roig, & Gómez-Ruano, 2016), which might also influence pacing. As regards to the statistical analyses, it is important to note that "statistically significant" outcomes were attributable simply to the high number of participants. Of more importance are the effect sizes that provide information about the practical meaningfulness of the findings.

Practical applications

The analysis of the pacing during four freestyle-swimming races in age groups of master swimmers is important for researchers involved in the study of performance in older athletes and for coaches working with master swimmers. Since this is the first study of pacing in master swimmers, researchers might use its findings as reference in future studies on pacing on master athletes. Coaches could consider the pacing patterns of these data as a guide in the development of pacing strategies for their athletes, because these data concern high-level swimmers who participated in the

World championship. Particularly, coaches should consider the sex- and age-related differences in pacing by setting sex- and age-tailored training goals. For instance, 200 m men swimmers should be advised to have smaller changes in swimming time from lap to lap than women. With regards to age variation of pacing, older age groups should be coached to decrease their swimming time in the last lap in 400 m more than their younger counterparts.

Conclusions

In summary, the largest increases in swimming time occurred during the second lap and the largest decreases in swimming time occurred during the last lap, except in the event of 100 m. The effect of a participants' sex was a larger percentage change of speed in women than in men swimmers and the effect of age group was greater than the effect of participants' sex.

References

Abbiss, C. R., & Laursen, P. B. (2008). Describing and understanding pacing strategies during athletic competition. *Sports Medicine, 38*(3), 239-252

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

Deaner, R. O., Carter, R. E., Joyner, M. J., & Hunter, S. K. (2014). Men are more likely than women to slow in the marathon. *Medicine and Science in Sports and Exercise, 47*(3), 607-616. doi: 10.1249/MSS.0000000000000432

Deaner, R. O., & Lowen, A. (2016). Males and females pace differently in High School cross country races. *Journal of Strength and Conditioning Research* 2016 Mar 3. [Epub ahead of print]

Edwards, A., & Polman, R. (2012). *Pacing in sport and exercise: a psychophysiological perspective.* Sports and Athletics Preparation, Performance and Psychology. Nova Science Publishers, New York.

Lipińska, P., Allen, S. V., & Hopkins, W. G. (2015). Relationships Between Pacing Parameters and Performance of Elite Male 1500-M Swimmers. *International Journal of Sports Physiology and Performance*, doi: 10.1123/ijspp.2015-0117

Lipińska, P., Allen, S. V., & Hopkins, W. G. (2016). Modeling parameters that characterize pacing of elite female 800-m freestyle swimmers. *European Journal of Sport Science, 16*(3), 287-292. doi: 10.1080/17461391.2015.1013996

March, D. S., Vanderburgh, P. M., Titlebaum, P. J., & Hoops, M. L. (2011). Age, sex, and finish time as determinants of pacing in the marathon. *Journal of Strength and Conditioning Research, 25*(2), 386-391. doi: 10.1519/JSC.0b013e3181bffd0f

Mauger, A. R., Neuloh, J., & Castle, P. C. (2012). Analysis of pacing strategy selection in elite 400-m freestyle swimming. *Medicine and Science in Sports and Exercise, 44*(11), 2205-2212. doi: 10.1249/MSS.0b013e3182604b84

Reaburn, P., & Dascombe, B. (2008). Endurance performance in masters athletes. *European Review of Aging and Physical Activity, 5*(1), 31-42.

Reaburn, P., & Dascombe, B. (2009). Anaerobic performance in masters athletes. *European Review of Aging and Physical Activity, 6*(1), 39-53.

Robertson, E. Y., Pyne, D.B., Hopkins, W., & Anson, J.M. (2009). Analysis of lap times in international swimming competition. *Journal of Sports Sciences, 27*(4), 387-395. doi: 10.1080/02640410802641400

Rubin, R. T., & Rahe, R. H. (2010). Effects of aging in Masters swimmers: 40-year review and suggestions for optimal health benefits. *Open Access Journal of Sports Medicine, 1*, 39-44

Saavedra, J. M., Escalante, Y., Garcia-Hermoso, A., Arellano, R., & Navarro, F. (2012). A 12-year analysis of pacing strategies in 200- and 400-m individual medley in international swimming competitions. *Journal of Strength and Conditioning Research, 26*(12), 3289-3296. doi: 10.1519/JSC.0b013e318248aed5

Skorski, S., Faude, O., Caviezel, S., & Meyer, T. (2014). Reproducibility of pacing profiles in elite swimmers. *International Journal of Sports Physiology and Performance, 9*(2), 217-225. doi: 10.1123/ijspp.2012-0258

Tanaka, H., & Seals, D. R. (2008). Endurance exercise performance in Masters athletes: Age-associated changes and underlying physiological mechanisms. *Journal of Physiology, 586*(1), 55-63.

Thompson, K. G., Haljand, R., MacLaren, D.P. (2000). An analysis of selected kinematic variables in national and elite male and female 100-m and 200-m breaststroke swimmers. *Journal of Sports Sciences, 18*(6), 421-431.

Veiga, S., Roig, A., & Gómez-Ruano, M. A. (2016). Do faster swimmers spend longer underwater than slower swimmers at World Championships? *European Journal of Sport Science*, in print.

Table 1 Participants in the four swimming events by sex and age group

Age group	100 m		200 m		400 m		800 m	
(yrs)	Women	Men	Women	Men	Women	Men	Women	Men
25-29	80	84	49	46	33	23	33	15
30-34	63	97	52	52	35	33	29	27
35-39	64	82	67	44	36	36	47	29
40-44	76	103	65	61	35	27	46	39
45-49	77	107	83	72	42	40	61	46
50-54	102	133	96	73	75	37	92	44
55-59	69	108	66	89	44	54	45	55
60-64	51	66	42	52	40	26	52	38
65-69	42	51	41	38	28	26	37	38
70-74	24	46	31	40	20	25	24	33
75-79	19	23	14	26	14	16	14	12
80-84	11	9	12	7	7	13	7	10
85-89	8	3	4	1	2	2	2	2
90-94	4		4	1	3		3	
Total	690	912	626	602	413	358	492	388

Table 2 Performance (s) in the four swimming events by sex and age group

Age group (yrs)	100 m		200 m		400 m		800 m	
	Women	Men	Women	Men	Women	Men	Women	Men
25-29	66.77±3.32	58.25±3.25	146.60±6.97	130.98±6.89	312.24±20.24	285.28±19.97	655.25±45.17	578.24±34.07
30-34	67.01±3.83	59.88±3.10	149.46±9.22	134.46±6.77	315.07±18.06	283.61±17.10	669.48±34.27	587.87±38.13
35-39	67.97±4.02	60.92±3.10	153.07±11.29	135.25±7.64	316.45±21.71	289.97±15.28	680.42±48.33	603.06±36.63
40-44	71.78±5.31	62.81±3.62	159.16±12.42	139.35±8.06	327.83±25.04	293.68±15.10	697.18±61.17	617.59±36.21
45-49	73.22±5.92	64.37±4.41	163.53±15.65	141.75±9.39	339.57±29.98	296.37±21.45	733.49±70.73	623.81±47.52
50-54	77.73±7.47	66.21±5.11	174.27±18.20	149.26±10.98	361.55±34.47	306.42±25.50	766.52±80.03	644.08±54.13
55-59	80.13±8.32	69.10±5.03	180.88±20.94	156.31±12.97	379.33±41.74	326.42±23.52	776.83±93.55	679.47±51.08
60-64	85.27±9.57	71.70±6.10	192.93±25.46	164.06±14.27	401.36±49.75	331.68±30.10	849.22±106.59	707.44±67.52
65-69	92.14±10.21	75.89±6.30	205.51±26.83	170.31±14.07	425.37±40.16	364.94±32.79	881.05±100.06	767.43±75.25
70-74	98.82±10.91	81.16±7.85	222.57±23.91	186.06±14.47	464.42±39.32	392.75±34.12	1010.80±91.43	832.53±62.93
75-79	107.96±13.54	90.86±10.07	233.46±39.81	204.05±21.50	524.18±87.63	425.18±44.08	1008.38±154.75	871.68±71.56
80-84	124.59±18.93	99.20±10.21	267.43±40.61	236.73±22.79	551.88±87.09	473.18±57.60	1220.71±148.85	986.42±115.46
85-89	139.94±14.42	113.14±8.82	307.86±64.21	312.97	570.13±20.49	553.71±55.73	1188.77±23.10	1163.11±139.32
90-94	161.65±16.67		319.19±36.82	269.52	739.91±176.02		1296.00±82.30	

Table 3 Coefficients (C) and standard errors of estimate (SEE) from multi-variate regression models for race times of participants by sex and lap

		C	**SEE**	***p***
	Sex	4.58	0.36 (0.50)	<0.001
100 m	Lap	3.57	0.07 (0.10)	<0.001
	Interaction sex×lap	0.86	0.10 (0.14)	<0.001
	Sex	4.95	0.46 (0.28)	<0.001
200 m	Lap	1.54	0.04 (0.02)	<0.001
	Interaction sex×lap	0.27	0.06 (0.04)	<0.001
	Sex	5.52	0.63 (0.18)	<0.001
400 m	Lap	0.46	0.02 (0.01)	<0.001
	Interaction sex×lap	0.03	0.02 (0.01)	0.219
	Sex	11.79	1.13 (0.15)	<0.001
800 m	Lap	0.58	0.03 (<0.01)	<0.001
	Interaction sex×lap	0.04	0.04 (0.01)	0.348

* SEE is expressed in absolute values and as percentage of mean in brackets.

Table 4 Coefficients (C) and standard errors of estimate (SEE) from multi-variate regression models for race times of participants by lap and age group in women

	100 m			200 m			400 m			800 m		
	C	SEE	*p*	C	SEE	*p*	C	SEE	*p*	C	SEE	*p*
Lap	5.95	0.95 (1.21)	<0.001	3.04	0.52 (0.30)	<0.001	1.41	0.21 (0.06)	<0.001	1.05	0.35 (0.04)	0.003
Age group 25-29	-43.95	2.47 (3.14)	<0.001	-39.67	2.85 (1.62)	<0.001	-49.24	3.12 (0.89)	<0.001	-78.52	6.33 (0.81)	<0.001
Age group 30-34	-44.20	2.49 (3.17)	<0.001	-38.82	2.84 (1.61)	<0.001	-48.54	3.11 (0.89)	<0.001	-76.41	6.36 (0.81)	<0.001
Age group 35-39	-43.08	2.49 (3.17)	<0.001	-38.59	2.82 (1.60)	<0.001	-48.75	3.11 (0.89)	<0.001	-75.30	6.25 (0.8)	<0.001
Age group 40-44	-42.46	2.48 (3.15)	<0.001	-36.54	2.82 (1.60)	<0.001	-47.17	3.11 (0.89)	<0.001	-72.53	6.25 (0.8)	<0.001
Age group 45-49	-41.83	2.47 (3.14)	<0.001	-35.87	2.81 (1.60)	<0.001	-45.74	3.09 (0.88)	<0.001	-68.71	6.2 (0.79)	<0.001
Age group 50-54	-40.61	2.46 (3.13)	<0.001	-33.05	2.8 (1.59)	<0.001	-43.37	3.05 (0.87)	<0.001	-64.31	6.15 (0.79)	<0.001
Age group 55-59	-39.09	2.48 (3.15)	<0.001	-31.95	2.82 (1.60)	<0.001	-40.81	3.09 (0.88)	<0.001	-62.72	6.25 (0.8)	<0.001
Age group 60-64	-36.95	2.51 (3.19)	<0.001	-27.98	2.87 (1.63)	<0.001	-38.31	3.1 (0.88)	<0.001	-52.91	6.23 (0.8)	<0.001
Age group 65-69	-33.74	2.52 (3.21)	<0.001	-24.87	2.87 (1.63)	<0.001	-34.81	3.14 (0.89)	<0.001	-49.52	6.3 (0.8)	<0.001
Age group 70-74	-32.40	2.61 (3.32)	<0.001	-21.62	2.91 (1.65)	<0.001	-30.66	3.2 (0.91)	<0.001	-34.36	6.42 (0.82)	<0.001
Age group 75-79	-27.71	2.65 (3.37)	<0.001	-19.75	3.11 (1.77)	<0.001	-23.49	3.29 (0.94)	<0.001	-34.83	6.67 (0.85)	<0.001
Age group 80-84	-20.39	2.82 (3.59)	<0.001	-9.98	3.16 (1.79)	0.002	-18.29	3.57 (1.02)	<0.001	-7.34	7.24 (0.92)	0.311
Age group 85-89	-17.17	2.95 (3.75)	<0.001	-7.11	3.87 (2.20)	0.067	-17.40	4.72 (1.34)	<0.001	-12.58	9.58 (1.22)	0.190
Age group 90-94	0*	0*	-	0*	0*	-	0*	0*	-	0*	0*	-
Interaction lap×age group 25-29	-2.56	0.98 (1.25)	0.009	-1.39	0.54 (0.31)	0.010	-0.94	0.22 (0.06)	<0.001	-0.34	0.36 (0.05)	0.344
Interaction lap×age group 30-34	-2.31	0.98 (1.25)	0.019	-1.44	0.54 (0.31)	0.007	-1.01	0.22 (0.06)	<0.001	-0.42	0.37 (0.05)	0.254
Interaction lap×age group 35-39	-2.74	0.98 (1.25)	0.005	-1.18	0.53 (0.30)	0.028	-0.93	0.22 (0.06)	<0.001	-0.36	0.36 (0.05)	0.315
Interaction lap×age group 40-44	-1.88	0.98 (1.25)	0.054	-1.38	0.53 (0.30)	0.010	-0.97	0.22 (0.06)	<0.001	-0.51	0.36 (0.05)	0.156
Interaction lap×age group 45-49	-1.82	0.98 (1.25)	0.062	-1.22	0.53 (0.30)	0.021	-0.96	0.21 (0.06)	<0.001	-0.35	0.36 (0.05)	0.326
Interaction lap×age group 50-54	-1.13	0.97 (1.23)	0.244	-1.25	0.53 (0.30)	0.018	-0.87	0.21 (0.06)	<0.001	-0.41	0.35 (0.04)	0.247
Interaction lap×age group 55-59	-1.35	0.98 (1.25)	0.169	-1.04	0.53 (0.30)	0.051	-0.95	0.21 (0.06)	<0.001	-0.48	0.36 (0.05)	0.185

Interaction lap×age group 60-64	-1.06	0.99 (1.26)	0.284	-1.40	0.54 (0.31)	0.010	-0.89	0.22 (0.06)	<0.001	-0.65	0.36 (0.05)	0.071
Interaction lap×age group 65-69	-0.91	1 (1.27)	0.360	-1.42	0.54 (0.31)	0.009	-1.00	0.22 (0.06)	<0.001	-0.52	0.36 (0.05)	0.154
Interaction lap×age group 70-74	0.43	1.03 (1.31)	0.679	-0.99	0.55 (0.31)	0.074	-0.84	0.22 (0.06)	<0.001	-0.28	0.37 (0.05)	0.447
Interaction lap×age group 75-79	0.42	1.05 (1.34)	0.688	-0.67	0.59 (0.34)	0.253	-0.77	0.23 (0.07)	0.001	-0.24	0.38 (0.05)	0.525
Interaction lap×age group 80-84	1.01	1.11 (1.41)	0.363	-1.18	0.6 (0.34)	0.048	-1.16	0.25 (0.07)	<0.001	-0.46	0.42 (0.05)	0.274
Interaction lap×age group 85-89	3.99	1.17 (1.49)	0.001	1.71	0.73 (0.41)	0.020	-0.85	0.33 (0.09)	0.010	-0.18	0.55 (0.07)	0.747
Interaction lap×age group 90-94	0*	0*	-	0*	0*	-	0*	0*	-	0*	0*	-

*This age group has been set to zero, because this parameter is redundant. SEE is expressed in absolute values and as percentage of mean in brackets.

Table 5 Coefficients (C) and standard errors of estimate (SEE) from multi-variate regression models for race times of participants by lap and age group in men

	100 m			200 m			400 m			800 m		
	C	**SEE**	***p***	**C**	**SEE**	***p***	**C**	**SEE**	***p***	**C**	**SEE**	***p***
Lap	5.95	0.95 (1.42)	<0.001	3.08	0.86 (0.56)	<0.001	0.34	0.23 (0.07)	0.133	0.18	0.40 (0.06)	0.659
Age group 25-29	-13.53	2.05 (3.07)	<0.001	-30.83	3.65 (2.38)	<0.001	-33.93	2.67 (0.82)	<0.001	-75.34	5.60 (0.81)	<0.001
Age group 30-34	-13.11	2.04 (3.05)	<0.001	-29.83	3.64 (2.37)	<0.001	-33.99	2.64 (0.81)	<0.001	-73.90	5.45 (0.79)	<0.001
Age group 35-39	-12.44	2.05 (3.07)	<0.001	-29.07	3.65 (2.38)	<0.001	-33.66	2.63 (0.80)	<0.001	-72.38	5.44 (0.79)	<0.001
Age group 40-44	-11.88	2.04 (3.05)	<0.001	-28.46	3.64 (2.37)	<0.001	-32.63	2.65 (0.81)	<0.001	-70.32	5.39 (0.78)	<0.001
Age group 45-49	-11.44	2.04 (3.05)	<0.001	-27.87	3.63 (2.36)	<0.001	-32.62	2.63 (0.80)	<0.001	-69.63	5.37 (0.78)	<0.001
Age group 50-54	-10.52	2.04 (3.05)	<0.001	-26.16	3.63 (2.36)	<0.001	-31.31	2.63 (0.80)	<0.001	-67.03	5.38 (0.78)	<0.001
Age group 55-59	-9.66	2.04 (3.05)	<0.001	-24.49	3.63 (2.36)	<0.001	-29.32	2.61 (0.80)	<0.001	-61.90	5.35 (0.78)	<0.001
Age group 60-64	-8.18	2.06 (3.08)	<0.001	-22.37	3.64 (2.37)	<0.001	-27.83	2.66 (0.81)	<0.001	-58.85	5.40 (0.79)	<0.001
Age group 65-69	-6.34	2.07 (3.10)	0.002	-20.65	3.66 (2.38)	<0.001	-23.37	2.66 (0.81)	<0.001	-51.44	5.40 (0.79)	<0.001
Age group 70-74	-4.85	2.08 (3.11)	0.020	-18.30	3.65 (2.38)	<0.001	-21.26	2.66 (0.81)	<0.001	-43.34	5.42 (0.79)	<0.001
Age group 75-79	0.48	2.14 (3.2)	0.823	-12.96	3.68 (2.40)	<0.001	-16.99	2.72 (0.83)	<0.001	-34.44	5.68 (0.83)	<0.001
Age group 80-84	0.02	2.32 (3.47)	0.992	-4.20	3.86 (2.51)	0.277	-11.83	2.75 (0.84)	<0.001	-21.58	5.76 (0.84)	<0.001
Age group 85-89	0*	0*	-	9.23	5.10 (3.32)	0.071	0*	0*	-	0*	0*	-
Interaction lap×age group 25-29	-9.27	0.96 (1.44)	<0.001	-1.52	0.87 (0.57)	0.079	0.08	0.24 (0.07)	0.724	0.50	0.43 (0.06)	0.249
Interaction lap×age group 30-34	-9.02	0.96 (1.44)	<0.001	-1.57	0.86 (0.56)	0.069	0.05	0.24 (0.07)	0.831	0.44	0.42 (0.06)	0.289
Interaction lap×age group 35-39	-9.11	0.96 (1.44)	<0.001	-1.80	0.87 (0.57)	0.038	0.15	0.23 (0.07)	0.512	0.53	0.42 (0.06)	0.205
Interaction lap×age group 40-44	-8.86	0.95 (1.42)	<0.001	-1.63	0.86 (0.56)	0.060	0.03	0.24 (0.07)	0.903	0.47	0.41 (0.06)	0.251
Interaction lap×age group 45-49	-8.63	0.95 (1.42)	<0.001	-1.62	0.86 (0.56)	0.060	0.10	0.23 (0.07)	0.665	0.49	0.41 (0.06)	0.231
Interaction lap×age group 50-54	-8.63	0.95 (1.42)	<0.001	-1.56	0.86 (0.56)	0.070	0.09	0.23 (0.07)	0.708	0.48	0.41 (0.06)	0.247
Interaction lap×age group 55-59	-8.24	0.95 (1.42)	<0.001	-1.53	0.86 (0.56)	0.077	0.20	0.23 (0.07)	0.384	0.32	0.41 (0.06)	0.433
Interaction lap×age group 60-64	-8.36	0.96 (1.44)	<0.001	-1.59	0.86 (0.56)	0.065	0.02	0.24 (0.07)	0.943	0.42	0.41 (0.06)	0.310
Interaction lap×age group 65-69	-8.19	0.97 (1.45)	<0.001	-1.66	0.87 (0.57)	0.056	-0.05	0.24 (0.07)	0.832	0.44	0.41 (0.06)	0.287

Interaction lap×age group 70-74	-7.42	0.97 (1.45)	<0.001	-1.03	0.87 (0.57)	0.236	0.25	0.24 (0.07)	0.286	0.45	0.42 (0.06)	0.280
Interaction lap×age group 75-79	-7.75	1 (1.50)	<0.001	-1.36	0.87 (0.57)	0.119	0.21	0.24 (0.07)	0.396	-0.44	0.44 (0.06)	0.310
Interaction lap×age group 80-84	-4.68	1.09 (1.63)	<0.001	-1.60	0.92 (0.60)	0.081	0.39	0.25 (0.08)	0.111	-0.11	0.44 (0.06)	0.799
Interaction lap×age group 85-89	0*	0*	-	0.65	1.21 (0.79)	0.591	0*	0*	-	0*	0*	-

*This age group has been set to zero, because this parameter is redundant.

Figure legends

Figure 1 Changes in swimming time by laps in 100 m, 200 m, 400 m and 800 m in women (dashed line) and men (solid line)

Figure 2 Changes in swimming time by laps in 100 m, 200 m, 400 m and 800 m by age groups in women and men

Figure 3 Difference (%) in swimming time between consecutive laps in 100 m, 200 m, 400 m and 800 m

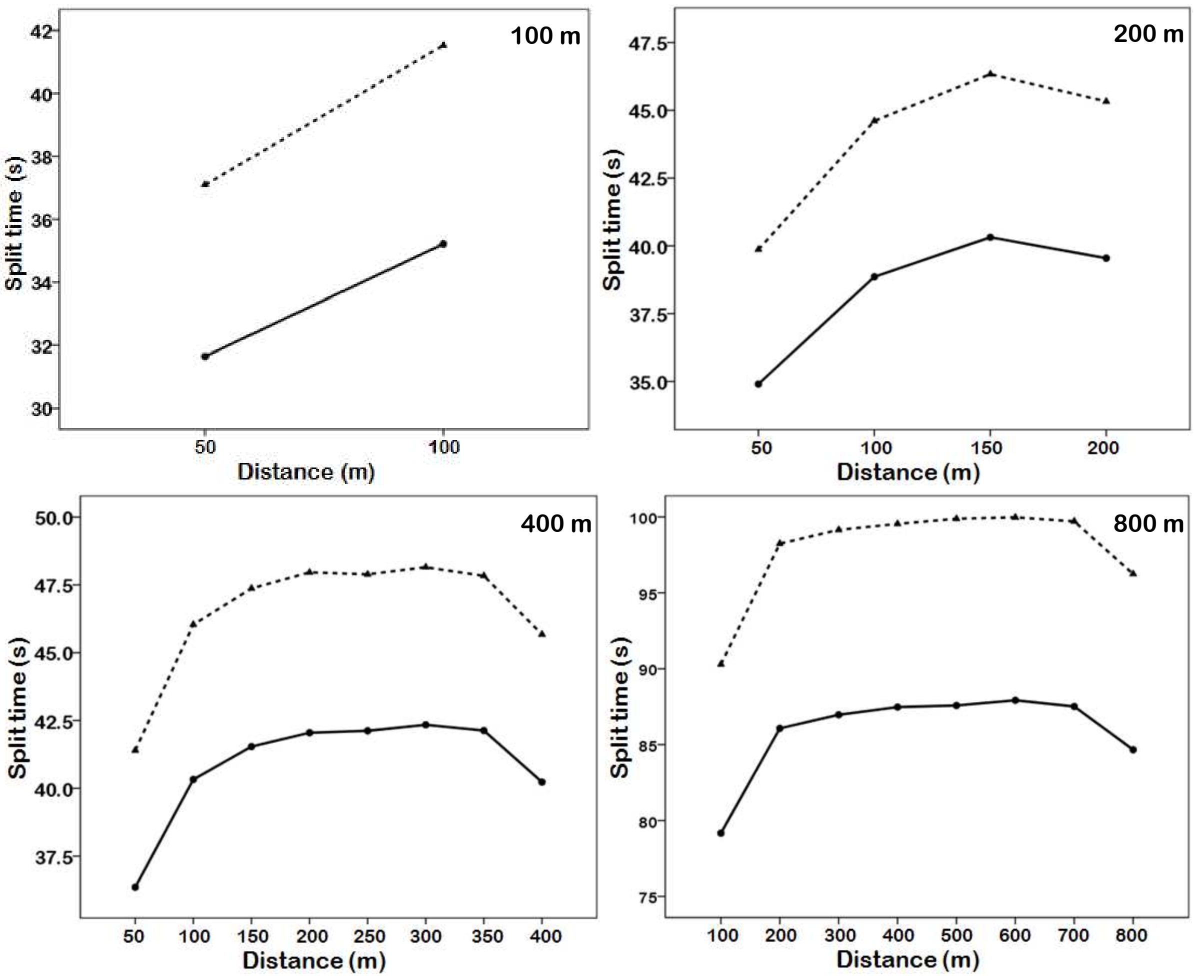
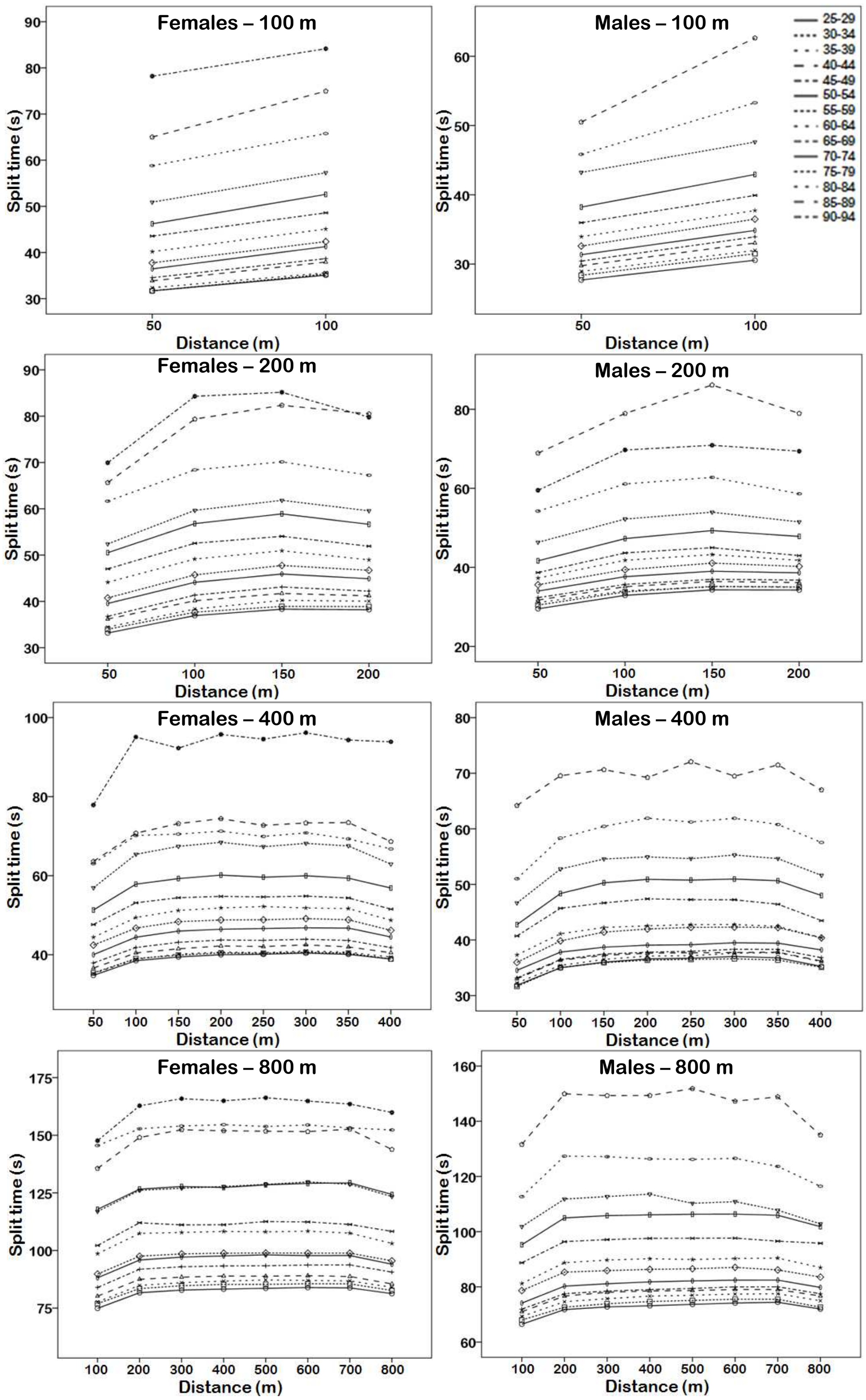


Figure 1



Females – 100 m
Males – 100 m
Females – 200 m
Males – 200 m
Females – 400 m
Males – 400 m
Females – 800 m
Males – 800 m
Split time (s)
Distance (m)
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
80-84
85-89
90-94

Figure 2

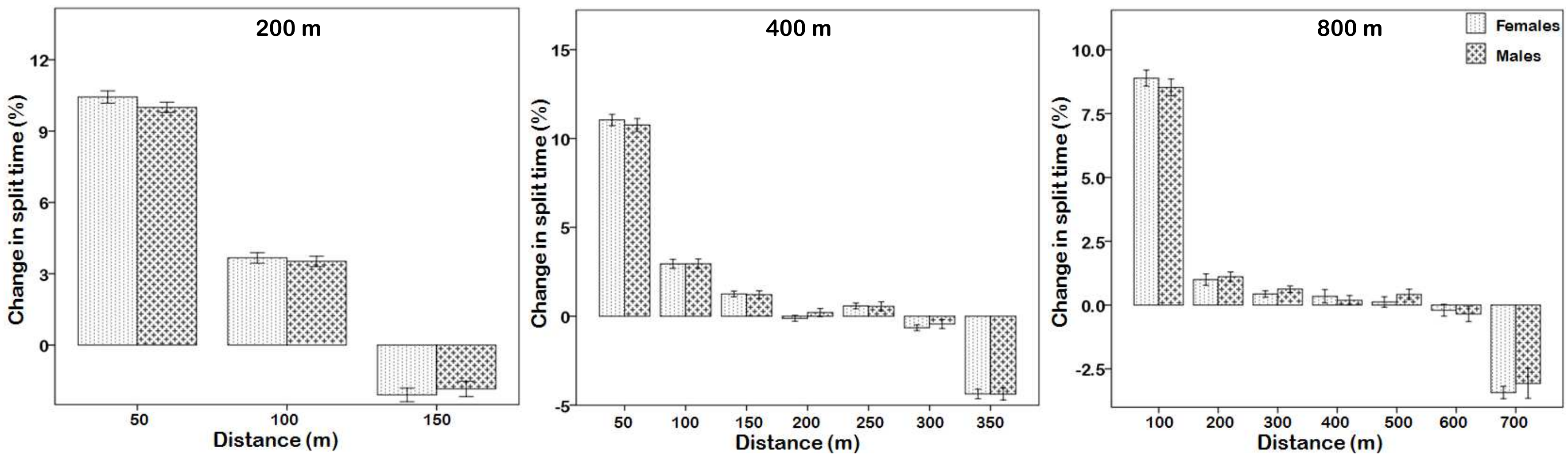

200 m
400 m
800 m
Females
Males
Change in split time (%)
Distance (m)
12
9
6
3
0
50
100
150
15
10
5
0
-5
50
100
150
200
250
300
350
10.0
7.5
5.0
2.5
0.0
-2.5
100
200
300
400
500
600
700

Figure 3